CLAIMS

1. An apparatus for generating characterization data characterizing features in an image comprising:

an image data receiver for receiving data representative of an image;

a feature detector for detecting the presence of features represented by image data received by said image data receiver, said feature detector being arranged to determine, for image data representative of a plurality of different sized regions of an image, values representative of the presence of features in said regions; and

an image point characteriser for characterizing image points selected as being representative of features in said image data on the basis of said detection by said feature detector, by calculating characterization values for said features, wherein said characterization values are determined utilizing image data for regions of the image including said feature, and wherein said image point characteriser is arranged to determine said characterization values on the basis of image data for different sized regions, said size of said region being selected on the basis of the size of a said region utilized to detect the said feature by said feature

detector.

2. Apparatus in accordance with claim 1, wherein said apparatus is arranged to associate with each of said plurality of different sized regions for determination of the presence of features, a size of region to be utilized to determine characterization values for features detected utilizing said different sized regions.

3. Apparatus according to claim 1, wherein said image point characteriser is arranged to select the size of region to be used to calculate the characterization values for a feature from a plurality of predetermined sizes, the selected size increasing as the size of the region used by the feature detector to detect said feature increases.

4. Apparatus in accordance with any of claim 1, wherein said feature characteriser is arranged to characterize each said region in a manner which is substantially independent of transformations resulting in linear distortions of the portion of said image including said region.

5. Apparatus in accordance with any of claim 1, wherein

said feature characteriser is arranged to characterize each said region in a manner which is substantially independent of rotational transformations of the portion of said image including said region.

6. Apparatus in accordance with claim 5, wherein said feature characteriser is arranged to utilize a substantially circular region to characterize a feature wherein the size of said circular region is selected on the basis of the size of said feature detected by said feature detector.

7. Apparatus in accordance with claim 1, further comprising a correspondence identifier for identifying the correspondence between features in a pair of images, wherein said corresponding identifier is arranged to determine a match between features in said pair of images characterized by said feature characteriser.

8. Apparatus in accordance with claim 1, further comprising:

a data store for storing characterization values for features in a plurality of images; and

a correspondence identifier, said correspondence identifier being arranged to determine a match between

characterization values determined by said feature characteriser for data representative of an image received by said image data receiver and stored characterization values stored in said data store.

9. An apparatus for generating a three-dimensional model of an object comprising:

apparatus for identifying a correspondence between features in pairs of images in accordance with claim 7;

a viewpoint determinator for determining on the basis of correspondence of features in pairs of images the relative positions from which said images have been obtained; and

a model generator for generating a three-dimensional model of an object utilizing said image data received by said image data receiver and said relative positions determined by said viewpoint determinator.

10. In an apparatus for generating a three-dimensional computer model of an object by processing images of the object taken from a plurality of different viewpoints to match features in the images, calculating the viewpoints at which the images were recorded using the matched features, and generating a three-dimensional computer model of the surface object using the calculated

viewpoints, an improvement comprising matching features in the images by:

storing image data;

detecting the presence of features in the images represented by stored image data utilizing a plurality of different sized regions of said image to determine values representative of the presence of features in said image data;

characterizing image points selected as being representative of features in said image data on the basis of said values, utilizing different sized regions of said image for said image points wherein the size of a region used to characterize and image point is selected on the basis of the size of the region utilized to determine a value representative of the presence of features in said image data for said image point, and

matching said features utilizing said characterizations.

11. In an apparatus for processing data defining images of an object to generate a three-dimensional computer model of the object by matching features in the images, calculating the viewpoints at which the images were recorded using the matched features, and generating a three-dimensional computer model of the surface of the

object using the calculated viewpoints, a method of performing the processing to match the features in the images comprising:

storing image data;

detecting the presence of features in the images represented by stored image data utilizing a plurality of different sized regions of said image to determine values representative of the presence of features in said image data;

characterizing image points selected as being representative of features in said image data on the basis of said values, utilizing different sized regions of said image for said image points wherein the size of a region used to characterize and image point is selected on the basis of the size of the region utilized to determine a value representative of the presence of features in said image data for said image point; and

matching said features utilizing said characterizations.

12. A method of generating characterization data characterizing features in an image comprising the steps of:

receiving image data;

detecting the presence of features represented by

received image data by determining for image data representative of a plurality of different sized regions of the image, values representative of the presence of features in said regions; and

characterizing image points selected as being representative of features in said image data on the basis of said detection by calculating characterization values for said features, wherein said characterization values are determined utilizing image data for regions of the image centred on said feature, and wherein the size of a said region for generating characterization data is selected on the basis of the size of said region utilized to detect said feature.

13. A method in accordance with claim 12, further comprising the steps of:

storing a plurality of sizes of regions for calculating characterization values; and

selecting from said stored sizes the size of regions for calculating characterization values for a feature, wherein the size selected increases as the size of the region used to detect said feature increases.

14. A method in accordance with claim 12, wherein said characterization step comprises generating

characterization values which characterize each said region in a manner which is substantially independent of transformations resulting in linear distortions of the portion of said image including said region.

15. A method in accordance with claim 14, wherein said characterization step comprises generating characterization values which characterize each said region in a manner which is substantially independent of rotational transformations of the portion of said image in said region.

16. A method in accordance with claim 15, wherein said characterization step utilizes a substantially circular region to generate characterization values to characterize a feature, and wherein said size of the circular region is selected on the basis of the size of said feature detected by said detection means.

17. A method of identifying the correspondence between features in a pair of images, comprising generating characterization data in accordance with claim 12; and

determining a match between features in said pair of images characterized by said characterization step.

18. A method in accordance with claim 17, further comprising the step of generating a signal conveying information defining identified correspondences.

19. A method in accordance with claim 18, further comprising the step of recording said signal on a recording medium either directly or indirectly.

20. A method of generating three-dimensional models from images of objects taken from different viewpoints comprising:

identifying the correspondence between features in images in accordance with claim 17;

determining the relative positions from which said images were obtained on the basis of said correspondence; and

generating a three-dimensional model of an object on the basis of said image data and said relative positions.

21. Apparatus for generating characterization data characterizing image data in a manner substantially independent of rotational transformations of said image data comprising:

an image data receiver for receiving image data;

a coefficient calculator for generating a set of

coefficients representative of the content of said image data; and

a characterization value generator for generating a set of characterization values utilizing coefficients generated by said coefficient calculator wherein said characterization values are substantially independent of rotational transformations of said image data;

characterized in that said coefficient calculator is arranged to generate complex coefficients comprising approximations of:

$$U_{n,m} = \int\int F_n(r) e^{im\theta} I(r,\theta) dr d\theta$$

where $F_n(r)$ is a set of circular symmetric functions, $I(r,\theta)$ is an image represented by the received image data and n,m are natural numbers.

22. Apparatus in accordance with claim 21, wherein said coefficient calculator is arranged to generate a set of complex coefficients for all values of n and m where

$0 \leq n \leq n_{max}$ $0 \leq m \leq m_{max}$

23. Apparatus in accordance with claim 22, wherein said characterization value generator is arranged to calculate

as a value indicative of the content of said image data substantially independent of rotational transformations of said image data, the value of the real portion of $U_{n,0}$ for $0 \leq n \leq n_{max}$.

24. Apparatus in accordance with claim 22, wherein said characterization value generator is arranged to calculate as a value indicative of the content of said image data substantially independent of rotational transformations of said image data, the value of the modulus of $U_{0,m}$ for $0 \leq m \leq m_{max}$.

25. Apparatus in accordance with claim 22, wherein said characterization value generator is arranged to calculate as a value indicative of the content of said image data substantially independent of rotational transformations of said image data, the value of the real portions of the product of $U_{m,n}$ and the complex conjugate of $U_{0,m}$ for $1 \leq m \leq m_{max}$, $1 \leq m \leq m_{max}$.

26. Apparatus in accordance with any of claim 22, wherein said characterization value generator is arranged to calculate as a value indicative of the content of said image data substantially independent of rotational transformations of said image data, the value of the

imaginary portions of the product of $U_{m,n}$ and the complex conjugate of $U_{0,m}$ for $1 \leq m \leq m_{max}$, $1 \leq m \leq m_{max}$.

27. Apparatus in accordance with claim 21, wherein said image data receiver is arranged to receive colour image data, and wherein said coefficient calculator is arranged to generate coefficients for monochrome images for each of the colour components for an image represented by colour image data received by image data receiver.

28. Apparatus in accordance with claim 27, wherein said characterization value generator is arranged to calculate as a value indicative of the content of said image data substantially independent of rotational transformations of said image data, the value of the real portion of $U_{n,0}$ for $0 \leq n \leq n_{max}$ for each of said monochrome images.

29. Apparatus in accordance with claim 27, wherein said characterization value generator is arranged to calculate as a value indicative of the content of said image data substantially independent of rotational transformations of said image data, the value of the modulus of $U_{0,m}$ for $0 \leq m \leq m_{max}$ for each of said monochrome images.

30. Apparatus in accordance with claim 27, wherein said

characterization value generator is arranged to calculate as a value indicative of the content of said image data substantially independent of rotational transformations of said image data, the value of the real portions of the product of $U_{m,n}$ and the complex conjugate of $V_{0,m}$ for $1 \leq m \leq m_{max}$, $1 \leq m \leq m_{max}$, for each of the monochrome images where $V_{0,m}$ is the complex conjugate for $U_{0,m}$ for one of the monochrome images.

31. Apparatus in accordance with claim 27, wherein said characterization value generator is arranged to calculate as a value indicative of the content of said image data substantially independent of rotational transformations of said image data, the value of the imaginary portions of the product of $U_{m,n}$ and the complex conjugate of $V_{0,m}$ for $1 \leq m \leq m_{max}$, $1 \leq m \leq m_{max}$, for each of the monochrome images where $V_{0,m}$ is the complex conjugate for $U_{0,m}$ for one of the monochrome images.

32. Apparatus in accordance with claim 27, wherein said characterization value generator is arranged to calculate as a value indicative of the content of said image data substantially independent of rotational transformations of said image data, the real portions of the product of $U_{n,m}$ for a monochrome image and the complex conjugate of

$U_{0,m}$ calculated for a different monochrome image.

33. An apparatus for identifying points within pairs of images of an object corresponding to the same physical point on the object comprising:

apparatus for characterizing points in images on the basis of image data including a said point in accordance with claim 21; and

a correspondence identifier for identifying the correspondence between features in a pair of images, wherein said matching means is arranged to determine a match between features in a pair of images on the basis of the correlation between characterization values for said points determined by said characterization means.

34. An apparatus for generating a three-dimensional model of an object comprising:

apparatus for identifying correspondences between features in pairs of images in accordance with claim 33;

a viewpoint determinator for determining on the basis of correspondence of features in the pairs of images the relative positions from which said images have been obtained; and

a model generator for generating a three-dimensional model of an object utilizing said image data and said

determination of the relative positions from which said image data has been obtained.

35. In an apparatus for generating a three-dimensional computer model of an object by processing images of the object taken from a plurality of different viewpoints to match features in the images, calculating the viewpoints at which the images were recorded using the matched features, and generating a three-dimensional computer model of the surface object using the calculated viewpoints, an improvement comprising matching features in the images by:

storing image data;

detecting the presence of features in the images represented by the stored data;

characterizing features by calculating a set of complex coefficients comprising approximations of:

$$U_{n,m} = \int\int F_n(r) e^{im\theta} I(r,\theta) dr d\theta$$

where $F_n(r)$ is a set of n circular symmetric functions, $I(r,\theta)$ is an image represented by received image data including a said feature and n,m are natural numbers; and

matching features utilizing said calculated coefficients.

36. In an apparatus for processing data defining images of an object to generate a three-dimensional computer model of the object by matching features in the images, calculating the viewpoints at which the images were recorded using the matched features, and generating a three-dimensional computer model of the surface of the object using the calculated viewpoints, a method of performing the processing to match the features in the images comprising:

storing image data;

detecting the presence of features in the images represented by stored image data;

characterizing features by calculating a set of complex coefficients comprising approximations of:

$$U_{n,m}=\int\int F_n(r)e^{im\theta}I(r,\theta)drd\theta$$

where $F_n(r)$ is a set of n circular symmetric functions, $I(r,\theta)$ is an image represented by received image data including a said feature and n,m are natural numbers; and

matching features utilizing said calculated coefficients.

37. A method of generating characterization data characterizing image data in a manner substantially

independent of rotational transformations of said image data comprising the steps of:

receiving image data;

generating a set of coefficients representative of the content of said image data; and

generating a set of characterization values utilizing said generated coefficients, wherein said characterization values are substantially independent of rotational transformations of said image data;

characterized in that said coefficient generation step comprises the generation of a set of complex coefficients comprising approximations of:

where $F_n(r)$ is a set of n circular symmetric function, $I(r,\theta)$ is an image represented by received image data including a said feature and n,m are natural numbers.

$$U_{n,m} = \int\int F_n(r) e^{im\theta} I(r,\theta) dr d\theta$$

38. A method in accordance with claim 37, wherein said coefficient generation step comprises the generation of a set of complex coefficients for all values of n and m where

$0 \leq n \leq n_{max}$ $0 \leq m \leq m_{max}$

39. A method in accordance with claim 38, wherein said characterization value generation comprises calculating as a value indicative of the content of said image data substantially independent of rotational transformations of said image data the value of the real portion of $U_{n,0}$ for $0 \leq n \leq n_{max}$.

40. A method in accordance with claim 38, wherein said characterization value generation step comprises calculating as a value indicative of the content of said image data substantially independent of rotational transformations of said image data, the value of the modulus of $U_{0,m}$ for $0 \leq m \leq m_{max}$.

41. A method in accordance with claim 38, wherein said characterization value generation means is arranged to calculating as a value indicative of the content of said image data substantially independent of rotational transformations of said image data, the value of the real portions of the product of $U_{m,n}$ and the complex conjugate of $U_{0,m}$ for $1 \leq m \leq m_{max}$, $1 \leq m \leq m_{max}$.

42. A method in accordance with claim 38, wherein said characterization value generation step comprises calculating as a value indicative of the content of said

image data substantially independent of rotational transformations of said image data the value of the imaginary portions of the product of $U_{m,n}$ and the complex conjugate of $U_{0,m}$ for $1 \leq m \leq m_{max}$, $1 \leq m \leq m_{max}$.

43. A method in accordance with claim 37, wherein said image data comprises colour image data, and wherein said coefficient calculation step comprises a set of coefficients for monochrome images for each of the colour components for an image represented by said colour image data.

44. A method in accordance with claim 43, wherein said characterization value generation step comprises calculating as a value indicative of the content of said image data substantially independent of rotational transformations of said image data, the value of the real portion of $U_{n,0}$ for $0 \leq n \leq n_{max}$ for each of said monochrome images.

45. A method in accordance with claim 43, wherein said characterization value generation step comprises calculating as a value indicative of the content of said image data substantially independent of rotational transformations of said image data, the value of the

modulus of $U_{0,m}$ for $0 \leq m \leq m_{max}$ for each of said monochrome images.

46. A method in accordance with claim 43, wherein said characterization value generation step comprises calculating as a value indicative of the content of said image data substantially independent of rotational transformations of said image data, the value of the real portions of the product of $U_{n,m}$ and the complex conjugate of $V_{0,m}$ for $1 \leq m \leq m_{max}$, $1 \leq m \leq m_{max}$, for each of the monochrome images where $V_{0,m}$ is the complex conjugate for $U_{0,m}$ for one of the monochrome images.

47. A method in accordance with claim 43, wherein said characterization value generation step comprises calculating as a value indicative of the content of said image data substantially independent of rotational transformations of said image data, the value of the imaginary portions of the product of $U_{m,n}$ and the complex conjugate of $V_{0,m}$ for $1 \leq m \leq m_{max}$, $1 \leq m \leq m_{max}$, for each of the monochrome images where $V_{0,m}$ is the complex conjugate for $U_{0,m}$ for one of the monochrome images.

48. A method in accordance with claim 43, wherein said characterization value generation step comprises

calculating as a value indicative of the content of said image data substantially independent of rotational transformations of said image data, the real portions of the product of $U_{n,m}$ for a monochrome image and the complex conjugate of $U_{0,m}$ calculated for a different monochrome image.

49. A method of identifying points within pairs of images of an object corresponding to the same physical point on the object comprising the steps of:

characterizing points in images on the basis of image data including a said point in accordance with claim 37; and

identifying the correspondence between features in a pair of images, by determining a match between features in a pair of images on the basis of the correlation between characterization values for said points determined by said characterization step.

50. A method in accordance with claim 49, further comprising the step of generating a signal conveying information defining identified correspondences.

51. A method in accordance with claim 50, further comprising the step of recording said signal on a

recording medium either directly or indirectly.

52. A method of generating a three-dimensional model of an object comprising the steps of:

identifying correspondences between features in pairs of images in accordance with claim 49;

determining on the basis of correspondence of features in the pairs of images, the relative positions from which said images have been obtained; and

generating a three-dimensional model of an object utilizing said image data and said relative positions.

53. In a method for generating a three-dimensional computer model of an object by processing images of the object taken from a plurality of different viewpoints to match features in the images, calculating the viewpoints at which the images were recorded using the matched features, and generating a three-dimensional computer model of the surface object using the calculated viewpoints, an improvement comprising matching features in the images by:

receiving image data;

detecting the presence of features in the images represented by the received data;

characterizing features by calculating a set of

complex coefficients comprising approximations of:

$$U_{n,m}=\int\int F_n(r)e^{im\theta}I(r,\theta)drd\theta$$

where $F_n(r)$ is a set of n circular symmetric functions, $I(r,\theta)$ is an image represented by received image data including a said feature and n,m are natural numbers; and

matching features utilizing said calculated coefficients.

54. Apparatus for processing data characterizing features in at least two images comprising:

a characterization data receiver for receiving characterization data characterizing a plurality of features in a first image and a plurality of features in a second image;

a correspondence determinator for determining, for the features in said first image, correspondence values indicative of the correspondence of characterization data of said features and characterization data for at least some of said features in said second image, said correspondence determinator being arranged to utilize said correspondence values to determine for each of said features in said first image:

(i) a candidate match feature in said second image, being the feature in said second image associated

with a correspondence value indicating that said feature in said second image has characterization data which more closely corresponds to the characterization data of said feature in said first image than the characterization data of any of the other said features in said second image corresponds to the characterization data of said feature in said first image; and

(ii) an ambiguity score indicative of the extent to which the characterization data of said candidate match feature more closely corresponds to the characterization data of said feature in said first image than the characterization data of any of the other said features in said second image corresponds to the characterization data of said feature in said first image; and

a selector for selecting as matched features, features in said first image and associated candidate match features in said second image on the basis of said ambiguity scores determined by said correspondence determinator, regardless of the actual level of correspondence of characterization data for said features.

55. Apparatus in accordance with claim 54, further comprising:

an image data receiver for receiving image data; and

a characterization generator for generating said characterization data for a plurality of features in an image utilizing received image data.

56. Apparatus in accordance with claim 55, wherein said characterization generator is arranged to characterize features in images on the basis of image data for a region of said image centred on each said feature.

57. Apparatus in accordance with claim 56, wherein said characterization generator is arranged to characterize each said region in a manner which is substantially independent of transformations resulting in linear distortions of said region of said image.

58. Apparatus for generating a three-dimensional computer model of an object comprising:

apparatus for processing data characterizing features in at least two images in accordance with claim 55;

a viewpoint determinator for determining on the basis of said selected matched features, the relative viewpoints from which images have been obtained; and

a model generator for generating a three-dimensional

computer model of an object utilizing said image data, and said determination of the relative positions from which said image data has been obtained.

59. In an apparatus for generating a three-dimensional computer model of an object by processing images of the object taken from a plurality of different viewpoints to match features in the images, calculating the viewpoints at which the images were recorded using the matched features, and generating a three-dimensional computer model of the surface object using the calculated viewpoints, an improvement comprising matching features in pairs of the images by:

storing image data;

detecting the presence of features in the images represented by the stored data;

generating characterization data for detected features;

determining for the features in one image of a pair of images correspondence values indicative of the correspondence of characterization data of said features and characterization data for at least some of said features in the other image;

utilizing said correspondence values to determine for each of said features in one of said pair of images:

(i) a candidate match feature in said other image, being the feature in said other image associated with a correspondence value indicating that said feature in said other image has characterization data which more closely corresponds to the characterization data of said feature in said one image than the characterization data of any of the other said features in said other image corresponds to the characterization data of said feature in said one image; and

(ii) an ambiguity score indicative of the extent to which the characterization data of said candidate match feature more closely corresponds to the characterization data of said feature in said one image than the characterization data of any of the other said features in said other image corresponds to the characterization data of said feature in said one image; and

selecting as matched features, features in said one image and associated candidate match features in said other image on the basis of determined ambiguity scores regardless of the actual level of correspondence of characterization data for said features.

60. In an apparatus for processing data defining images

of an object to generate a three-dimensional computer model of the object by matching features in the images, calculating the viewpoints at which the images were recorded using the matched features, and generating a three-dimensional computer model of the surface of the object using the calculated viewpoints, a method of performing the processing to match the features in pairs of the images comprising:

receiving image data;

detecting the presence of features in the images represented by received image data;

generating characterization data for detected features;

determining for the features in one image of a pair of images correspondence values indicative of the correspondence of characterization data of said features and characterization data for at least some of said features in the other image;

utilizing said correspondence values to determine for each of said features in said one of said pair of images:

(i) a candidate match feature in said other image, being the feature in said other image associated with a correspondence value indicating that said feature in said other image has characterization

data which more closely corresponds to the characterization data of said feature in said one image than the characterization data of any of the other said features in said other image corresponds to the characterization data of said feature in said one image; and

(ii) an ambiguity score indicative of the extent to which the characterization data of said candidate match feature more closely corresponds to the characterization data of said feature in said one image than the characterization data of any of the other said features in said other image corresponds to the characterization data of said feature in said one image; and

selecting as matched features, features in said one image and associated candidate match features in said other image on the basis of determined ambiguity scores regardless of the actual level of correspondence of characterization data for said features.

61. A method of processing data characterizing features in at least two images comprising:

receiving characterization data characterizing a plurality of features in a first image and a plurality of features in a second image;

determining for the features in said first image correspondence values indicative of the correspondence of characterization data of said features and characterization data for at least some of said features in said second image;

utilizing said correspondence values to determine for each of said features in said first image:

(i) a candidate match feature in said second image, being the feature in said second image associated with a correspondence value indicating that said feature in said second image has characterization data which more closely corresponds to the characterization data of said feature in said first image than the characterization data of any of the other said features in said second image corresponds to the characterization data of said feature in said first image; and

(ii) an ambiguity score indicative of the extent to which the characterization data of said candidate match feature more closely corresponds to the characterization data of said feature in said first image than the characterization data of any of the other said features in said second image corresponds to the characterization data of said feature in said first image; and

selecting as matched features, features in said first image and associated candidate match features in said second image on the basis of determined ambiguity scores regardless of the actual level of correspondence of characterization data for said features.

62. A method in accordance with claim 61, further comprising the steps of:

receiving image data; and

generating characterization data characterizing a plurality of features in received images.

63. A method in accordance with claim 62, wherein said characterization step comprises characterizing features in images on the basis of image data for a region of said image centred on said feature.

64. A method in accordance with claim 63, wherein said characterization step comprises characterizing said region in a manner which is substantially independent of transformations resulting in linear distortions of said portion of said image.

65. A method in accordance with claim 61 further comprising the step of generating a signal conveying

information defining said selected matched pairs of features.

66. A method in accordance with claim 65, further comprising the step of recording said generated signal on a recording medium either directly or indirectly.

67. A method for generating three-dimensional computer models of an object comprising the steps of:

processing data characterizing features in at least two of images of the images in accordance with claim 62;

determining on the basis of said matched features, the relative viewpoints from which images have been obtained; and

generating a three-dimensional computer model of an object utilizing said image data, and said determination of the relative positions from which said image data has been obtained.

68. In a method for generating a three-dimensional computer model of an object by processing images of the object taken from a plurality of different viewpoints to match features in the images, calculating the viewpoints at which the images were recorded using the matched features, and generating a three-dimensional computer

model of the surface object using the calculated viewpoints, an improvement comprising matching features in pairs of the images by:

storing image data;

detecting the presence of features in the images represented by the stored data;

generating characterization data for detected features;

determining for the features in one image of a pair of images correspondence values indicative of the correspondence of characterization data of said features and characterization data for at least some of said features in the other image;

utilizing said correspondence values to determine for each of said features in one of said pair of images:

(i) a candidate match feature in said other image, being the feature in said other image associated with a correspondence value indicating that said feature in said other image has characterization data which more closely corresponds to the characterization data of said feature in said one image than the characterization data of any of the other said features in said other image corresponds to the characterization data of said feature in said one image; and

(ii) an ambiguity score indicative of the extent to which the characterization data of said candidate match feature more closely corresponds to the characterization data of said feature in said one image than the characterization data of any of the other said features in said other image corresponds to the characterization data of said feature in said one image; and

selecting as matched features, features in said one image and associated candidate match features in said other image on the basis of determined ambiguity scores regardless of the actual level of correspondence of characterization data for said features.

69. In a method for generating a three-dimensional computer model of an object by processing images of the object taken from a plurality of different viewpoints to match features in the images, calculating the viewpoints at which the images were recorded using the matched features, and generating a three-dimensional computer model of the surface object using the calculated viewpoints, an improvement comprising matching features in the images by:

storing image data;

detecting the presence of features in the images

represented by stored image data utilizing a plurality of different sized regions of the images to determine values representative of the presence of features in said image data;

characterizing image points selected as being representative of features in said image data on the basis of said values, utilizing different sized regions of said image for said image points wherein the size of a region used to characterize and image point is selected on the basis of the size of the region utilized to determine a value representative of the presence of features in said image data for said image point; and

matching said features utilizing said characterizations.

70. Apparatus for generating characterization data characterizing an image comprising:

a data receiver for receiving image data representative of an image;

a feature detector for detecting a plurality of features in an image represented by image data received by said data receiver; and

a feature characteriser for characterising features detected by said feature detector, said feature characteriser being arranged to characterise portions of

image data representative of regions of an image including features detected by said feature detector, wherein feature characteriser is arranged to generate characterization data for a said region of an image such that said characterization is substantially unaffected by transformations resulting in linear distortions of said region.

71. Apparatus in accordance with claim 72, wherein said feature detector is arranged to detect a plurality of different sizes of features, and wherein said feature characteriser is arranged to use the size of a feature detected by said feature detector to select the size of a said region used to generate characterization data for a said feature.

72. Apparatus in accordance with claim 70, wherein said feature characteriser is arranged to determine the shape of a region to be used to generate characterization data for a feature on the basis of values of image data for a region of said image including said feature so that said characterization is substantially unaffected by transformations resulting in linear distortions of said region of said image.

73. Apparatus in accordance with claim 70, wherein said feature characteriser comprises:

a luminance determinator for determining the rate of change of luminance along two axes for a said region of said image;

an image transformer for determining a transformed image utilizing said rates of change of luminance determined by said luminance detector; and

a characterisation generator for generating characterization data characterizing a said region of said image utilizing said transformed image.

74. Apparatus in accordance with claim 72, wherein said data receiver is arranged to receive image data representative of pixels within a said image, and said characterization data generator comprises:

an average second moment matrix determinator for determining for a said region an averaged second moment matrix for a feature, wherein said averaged second moment matrix comprises a scaled sum of second moment matrices for each pixel in said region, and said second moment matrices for each of said pixels comprises:

$$M = \begin{pmatrix} I_x^2 & I_x I_y \\ I_x I_y & I_y^2 \end{pmatrix}$$

where I_x and I_y are value indicative of the rate of change of luminance of an image along two different axes; and

a transformed region determinator for determining for a said region of said image including a said feature a transformed image for said region transformed to account for distortions arising from stretch and skew on the basis of said averaged second moment matrix determined for said region by said average second moment matrix determinator, said characterization data generator being arranged to calculate characterisation values for a said feature on the basis of the calculation of rotational invariants determined for a transformed image for said region including said feature transformed by said transformed region determinator.

75. Apparatus in accordance with claim 74, wherein said transformed region determinator is arranged to determine a transformed image by interpolating values for an inverse square root of a second moment matrix determined by said average second moment matrix determinator for said region to determine a transformed image representative of said region of said original image transformed by the square root of said second moment matrix multiplied by a scaling factor.

76. Apparatus in accordance with claim 75, wherein said scaling factor is inversely proportional to the square root of the determinant of the averaged second moment matrix for a said region.

77. Apparatus in accordance with claim 76, wherein said transformed region determinator is arranged to generate transformed image data for a said region of said image until the calculated second moment matrix determined by said second moment matrix determinator for said transformed image is equal to identity, and wherein said feature characteriser is arranged to characterize a said feature on the basis of said iteratively transformed image data.

78. Apparatus in accordance with claim 70 further comprising a feature associater for identifying matches between features in pairs of images, wherein said feature associator is arranged to determine a match between features in pairs of images on the basis of characterization by said feature characteriser of features in said pair of images.

79. Apparatus in accordance with claim 78, further comprising:

a data store for storing characterization data for features in a plurality of images, and

a feature associator, said feature associator being arranged to determine, utilizing the characterization of features of received image data characterized by said feature characteriser, a match between features in said received image data and features defined by characterization values stored in said data store.

80. Apparatus for generating data defining a three-dimensional computer model of an object comprising:

apparatus for identifying matches between features in pairs of images in accordance with claim 78;

a viewpoint determinator for determining on the basis of the matching of features in a pair of images by said apparatus the relative viewpoints from which said images have been recorded; and

a model generator for generating data defining a three-dimensional computer model of the object utilizing said image data in said images and said determination of the relative viewpoints from which said images have been recorded by said viewpoint determinator.

81. Apparatus for removing the effects of affine distortions from image data comprising:

an image receiver for receiving image data;

a transformation determinator for determining a transformation to remove affine distortions from image data received by said image receiver; and

a transformed image generator for generating transformed image data corresponding to image data received by said image receiver transformed by said transformation determined by said transformation determinator;

wherein said transformation determinator is arranged to determine the transformation to remove the effects of affine distortions from image data received by said image receiver by determining a transformation such that the second moment matrix for said image transformed by said transformation is substantially equal to the identity matrix.

82. Apparatus in accordance with claim 81, wherein said transformation determinator is arranged to determine said transformation by determining the square root of a second moment matrix for image data received by said image receiver.

83. Apparatus in accordance with claim 82, wherein said transformation determinator is arranged to calculate said

second moment matrix by determining the rate of change of luminance along two axes of image data received by said image receiver.

84. Apparatus in accordance with claim 81, wherein said transformed image generator is arranged to generate pixel data for said transformed image data by calculating the value of each pixel in the transformed image by determining the origin of the said pixel in the original image utilizing the inverse square root of a second moment matrix determined for said image received by said image receiver multiplied by a scaling factor inversely proportional to the square root of the determinant of said second moment matrix, and interpolating values for image data representative of the origin of the pixel in the image received by said image receiver.

85. Apparatus in accordance with claim 84, further comprising a second moment determinator for determining a second moment matrix for a transformed image generated by said transformed image generator, and wherein said transformation determinator and said transformed image generator are arranged to generate further transformed image data from said transformed image data, if said second moment determinator determines that the second

moment matrix for said transformed image is not substantially equal to identity.

86. Apparatus in accordance with claim 85, wherein said second moment determinator is arranged to determine the rate of change of luminance along two axes for a transformed matrix and to determine the second moment matrix for a transformed image utilizing said rates of change of luminance.

87. A method for generating characterization data characterizing an image comprising the steps of:

receiving image data representative of an image;

detecting a plurality of features in said image; and

generating characterization data, characterising said features, by generating data characterising portions of said image data representative of regions of images including said features, wherein said generation step is such that said characterization data generated is substantially unaffected by transformations resulting in linear distortions of said regions including said features.

88. A method in accordance with claim 87, wherein said determination step comprises detecting a plurality of

different sized features, wherein said characterisation step includes selecting the size of a region to characterize a said feature on the basis of said size of a said feature.

89. A method in accordance with claim 87, wherein said generation step comprises for each of said features determining the shape of a region to be used to characterize a said feature on the basis of values of image data for a region of said image including said feature so that said characterization is substantially unaffected by transformations resulting in linear distortions of said region of said image.

90. A method in accordance with claim 87, wherein said generation step comprises the steps of:

determining the rate of change of luminance along two axes for said regions of said images;

determining transformed images utilizing said rates of change of luminance; and

generating characterization data for said features utilizing said transformed images.

91. A method in accordance with claim 89, wherein said characterization step comprises the steps of:

determining for a said region of an image including a feature an averaged second moment matrix for said feature, wherein said averaged second moment matrix comprises a scaled sum of second moment matrices for each pixel in said region, and said second moment matrices for each of said pixels comprises:

$$M = \begin{pmatrix} I_x^2 & I_x I_y \\ I_x I_y & I_y^2 \end{pmatrix}$$

where I_x and I_y are values indicative of the rate of change of luminance of an image along two different axes; and

determining for said region of said image including said feature a transformed image transformed to account for distortions arising from sketch and skew on the basis of said second moment matrix determined for said region; and

calculating characterisation values for a feature on the basis of the calculation of rotational invariants determined for said transformed image.

92. A method in accordance with claim 91, wherein the determination of a transformed image comprises determining a transformed image corresponding to the

selected region transformed by the square root of said second moment matrix for said region scaled by a scaling factor.

93. A method in accordance with claim 92, wherein said scaling factor is proportional to the square root of the determinant of said second moment matrix determined for said region.

94. A method in accordance with claim 93, wherein said determination of a transformed image comprises determining a transformed image by interpolating values for the origins of pixels in the transformed image transformed by the inverse square root of said second moment matrix multiplied by a scaling factor, to determine a transformed image representative of said original image region transformed by the square root of said second moment matrix multiplied by a scaling factor, wherein said scaling factor is inversely proportional to the determinant of the second moment matrix for a said feature.

95. A method in accordance with claim 94, wherein said transformation step comprises iteratively generating transformed image data for a said region of said image

until the calculated second moment matrix for said transformed image is substantially equal to identity, and said characterization comprises means characterizing said feature on the basis of said iteratively transformed image data.

96. A method of identifying correspondences between features in pairs of images, comprising the steps of:

generating characterization data for images in accordance with claim 87; and

determining a match between features in pairs of images utilizing said characterization data.

97. A method in accordance with claim 96 further comprising the step of generating a signal conveying information defining said correspondences.

98. A method in accordance with claim 97, further comprising the step of recording said generated signal on a recording medium either directly or indirectly.

99. A method for generating a three-dimensional model from images of objects comprising the steps of:

identifying the correspondence between features in pairs of images in accordance with claim 96;

determining on the basis of the correspondence of features on a pair of images the relative viewpoints from which said images have been obtained; and

generating a three-dimensional model of an object utilizing said image data and said determination of the relative viewpoints from which said image data has been obtained.

100. A method for removing the effects of affine distortions from image data comprising:

receiving image data;

determining a transformation to remove affine distortions from receive image data; and

generating transformed image data corresponding to received image data transformed by said determined transformation;

wherein said determination step comprises the step of determining a transformation for an image where the second moment matrix for said image transformed by said transformation is substantially equal to the identify matrix.

101. A method in accordance with claim 100, wherein said generation step comprises generating said transformed image data on the basis of the interpolation of values

for image data representative of the origins of pixels in the transformed image transformed by the inverse square root of a second moment matrix determined for said image stored in said storage means multiplied by a scaling factor inversely proportional to the square root of the determinant of said second moment matrix.

102. A method in accordance with claim 101, further comprising the steps of determining a second moment matrix for a transformed image and generating further transformed image data from said transformed image data, if the second moment for said transformed image is not substantially equal to identity.

103. A method in accordance with claim 102, wherein said second moment matrix for a transformed image is determined by the steps of:

determining the rate of luminance along two axes for a said transformed image, and determining said second moment matrix utilizing said rates of change of luminance.

104. In an apparatus for generating a three-dimensional computer model of an object by processing images of the object taken from a plurality of different viewpoints to

match features in the images, calculating the viewpoints at which the images were recorded using the matched features, and generating a three-dimensional computer model of the surface object using the calculated viewpoints, an improvement comprising matching features in the images by:

storing image data;

detecting the presence of features in the images represented by stored image data,

generating characterization data for said features in the images in a manner substantially unaffected by linear distortions of regions of said images including a said feature; and

matching features in different images utilizing said generated characterization data.

105. In an apparatus for processing data defining images of an object to generate a three-dimensional computer model of the object by matching features in the images, calculating the viewpoints at which the images were recorded using the matched features, and generating a three-dimensional computer model of the surface of the object using the calculated viewpoints, a method of performing the processing to match the features in the images comprising:

storing image data;

detecting the presence of features in the images represented by stored image data,

generating characterization data for said features in the images in a manner substantially unaffected by linear distortions of regions of said images including a said feature; and

matching features in different images utilizing said generated characterization data.

106. In a method for generating a three-dimensional computer model of an object by processing images of the object taken from a plurality of different viewpoints to match features in the images, calculating the viewpoints at which the images were recorded using the matched features, and generating a three-dimensional computer model of the surface object using the calculated viewpoints, an improvement comprising matching features in the images by:

storing image data;

detecting the presence of features in the images represented by stored image data,

generating characterization data for said features in the images in a manner substantially unaffected by linear distortions of regions of said images including a

said feature; and

matching features in different images utilizing said generated characterization data.

107. An apparatus for identifying features in images comprising:

an image receiver for receiving data representative of an image;

a feature detector for detecting the presence of features in images represented by image data received by said image receiver, said feature detector being arranged to determine, for image data representative of a plurality of different sized regions of said image, values representative of the presence of features in said regions; and

a selector for selecting image points as being representative of features in said image data on the basis of said detection by said feature detector;

characterised in that:

said feature detector is arranged to scale said values indicative of the presence of a feature in an image to account for variation in said values arising due to the size of the region used to determine said values.

108. An apparatus in accordance with claim 107, wherein

said feature detector is arranged to scale said values by changing each of said values utilizing scaling factors proportional to the areas of regions used to determine said values.

109. An apparatus in accordance with claim 108, wherein said feature detector is arranged to scale said values by dividing each of said values by said scaling factors.

110. An apparatus in accordance with claim 107, wherein said selector is arranged to select points as being representative of features within images on the basis of said scaled values generated by said feature detector which exceed a predetermined threshold.

111. Apparatus in accordance with claim 107 wherein said selector is arranged to select a predetermined number of image points as being representative of features by comparing scaled values determined by said feature detector and selecting points being associated with values most strongly indicative of the presence of features.

112. Apparatus in accordance with claim 107, wherein said feature detector is arranged to determine the value for

a region utilizing an averaged value indicative of the presence of a feature in an image calculated for a said region of said image, and to scale said determined value.

113. An apparatus in accordance with claim 112, wherein said feature detector is arranged to, for each of said plurality of different sized regions:

(a) determine a smoothed image wherein each of the values for pixels in said smoothed image are determined on the basis of an averaged value for pixels in the said region in said original image;

(b) to determine characterization values for each of said pixels in said smoothed image indicative of the presence of a feature in said region; and

(c) to determine from pixels in said smoothed image a value indicative of an averaged characterization value for a region of said smoothed image, said size of said smoothed image region being proportional to said size of said region used to generate said smoothed image.

114. Apparatus in accordance with claim 113, wherein said characterisation values comprise values indicative of the rate of change of luminance of pixels in said smoothed image.

115. Apparatus in accordance with claim 114, wherein said feature detector is arranged to generate said values indicative of the presence of a said feature by calculating values for Harris corner strengths for said points, divided by a scaling factor proportional to the square of the area of the region of image used to determine said Harris corner strengths.

116. Apparatus in accordance with claim 107, further comprising a feature characteriser for characterising image points selected by said selector, said feature characteriser being arranged to characterize a selected image point on the basis of image data representative of a region of said image including said selected image point.

117. Apparatus in accordance with claim 116, wherein said feature characteriser is arranged to vary the size of a said region for characterizing an image point so that said size of said region is proportional to the size of the region utilized by said feature detector to determine a value which resulted in the selection by said selector of said image point, included in said region.

118. Apparatus in accordance with claim 117, wherein said

feature characteriser is arranged to characterise said region in a manner which is substantially independent of affine transformations of the image data of said region.

119. Apparatus in accordance with claim 116, further comprising a match identifier for identifying matches between features in a pair of images, wherein said match identifier is arranged to determine a match between image points in said pair of images characterised by said feature characteriser.

120. Apparatus in accordance with claim 118, further comprising a data store for storing characterisation values associated with image points in a plurality of images, and a match identifier, said match identifier being arranged to determine on the basis of said characterisation of features by said feature characteriser matches between image points in the image data received by said image receiver and image points associated with characterization values stored in said data store.

121. An apparatus for generating a three-dimensional computer model of an object comprising:

apparatus for identifying matches between features

in pairs of images in accordance with claim 119;

a viewpoint determinator for determining on the basis of the matches the relative view points from which said images have been obtained; and

a model generator for generating a three-dimensional computer model of an object utilizing said image data received by said image receiver and said determination of the relative view points from which said image data has been obtained determined by said viewpoint determinator.

122. In an apparatus for generating a three-dimensional computer model of an object by processing images of the object taken from a plurality of different viewpoints to match features in the images, calculating the viewpoints at which the images were recorded using the matched features, and generating a three-dimensional computer model of the surface object using the calculated viewpoints, an improvement comprising matching features in the images by:

storing image data;

detecting the presence of features in the images represented by the stored data, by determining, for image data representative of a plurality of different sized regions of a said image, values representative of the presence of features in said regions, and scaling said

values to account for variation in said values arising due to the size of the region used to determine said values; and

selecting image points as being representative of features in said image data on the basis of said scaled values.

123. In an apparatus for processing data defining images of an object to generate a three-dimensional computer model of the object by matching features in the images, calculating the viewpoints at which the images were recorded using the matched features, and generating a three-dimensional computer model of the surface of the object using the calculated viewpoints, a method of performing the processing to match the features in the images comprising:

storing image data;

detecting the presence of features in the images represented by stored image data, comprising determining for image data representative of a plurality of different sized regions of a said image, values representative of the presence of features in said regions, and scaling said values to account for variation in said values arising due to the size of the region used to determine said values; and

selecting image points as being representative of features in said image data on the basis of said scaled values.

124. A method for identifying features in images comprising the steps of:

storing image data;

detecting the presence of features in images represented by stored image data, said detection step comprising determining for image data representative of a plurality of different sized regions of said image, values representative of the presence of features in said regions; and

selecting image points as being representative of features in said image data on the basis of said detection step, characterised in that said detection step includes the step of scaling said values indicative of the presence of a feature in an image to account for variation in said values arising due to the size of the region used to determine said values.

125. A method in accordance with claim 124, wherein said scaling step comprises changing each of said values utilizing scaling factors proportional to the areas of the regions used to determine said values.

126. A method in accordance with claim 125, wherein said scaling step comprises scaling said values by dividing each of said values by said scaling factors.

127. A method in accordance with claim 124 wherein said selection step comprises selecting image points as being representative of features on the basis of said scaled values determined for a region including a said point exceeding a predetermined threshold.

128. A method in accordance with claim 124, wherein said selection step comprises selecting a predetermined number of image points as being representative of features by comparing scaled values determined for regions and selecting points associated with values most strongly indicative of the presence of features.

129. A method in accordance with claim 124, wherein said detection step comprises determining the value for a region utilizing an averaged value indicative of the presence of a feature in an image calculated for a said region of said image, and scaling said determined value.

130. A method in accordance with claim 129, wherein said detection step comprises, for each of said plurality of

different sized regions;

(a) determining a smoothed image wherein each of the values for pixels in said smoothed image are determined on the basis of an averaged value for pixels in the said region in said original image;

(b) determining characterization values for each of said pixels in said smoothed image indicative of the presence of a feature in said region; and

(c) determining from pixels in said smoothed image a value indicative of an averaged characterization value for a region of said smoothed image, said size of said smoothed image region being proportional to said size of said region used to generate said smoothed image.

131. A method in accordance with claim 130, wherein said characterisation values comprise values indicative of the rate of change of luminance of pixels in said smoothed image.

132. A method in accordance with claim 131, wherein said detection means is arranged to generate said values indicative of the presence of a said feature by calculating values for Harris corner strengths for said points, divided by a scaling factor proportional to the square of the area of the region of image used to

determine said Harris corner strength.

133. A method of characterizing features in images comprising the steps of selecting image points in accordance with claim 124, and characterizing features, on the basis of image data representative of regions of said image including said image points.

134. A method in accordance with claim 133, wherein said characterization step comprises selecting the size of a said region for characterizing a feature so that said size of a region for characterizing a feature is proportional to the size of the region utilized to determine a value utilized to select said image point, included in said region.

135. A method in accordance with claim 124, wherein said characterisation step comprises characterizing said region in a manner which is substantially independent of affine transformations of the image data of said region.

136. A method of identifying the correspondence between features in pairs of images comprising the steps of:

characterizing features in images in accordance with claim 133; and

identifying correspondence between features in a pair of images on the basis of said characterization in said characterization step.

137. A method in accordance with claim 136 further comprising the step of generating a signal conveying information defining identified correspondences.

138. A method in accordance with claim 137 further comprising the step of recording said generated signal on a recording medium either directly or indirectly.

139. A method of selecting an image from a database of images comprising the steps of:

storing characterization values for features in a plurality of images stored in a database;

characterizing an image in accordance with claim 133; and

selecting an image from a database on the basis of a comparison of said characterization of said image and said stored characterization values for features in images in said database.

140. A method of generating a three-dimensional model of an object comprising the steps of:

identifying a correspondence between features in pairs of images in accordance with claim 136;

determining on the basis of the correspondence of features in a pair of images the relative view points from which said images have been obtained; and

generating a three-dimensional model of an object utilizing said image data and said determination of the relative view points from which said image data has been obtained.

141. In a method of generating a three-dimensional computer model of an object by processing images of the object taken from a plurality of different viewpoints to match features in the images, calculating the viewpoints at which the images were recorded using the matched features, and generating a three-dimensional computer model of the surface object using the calculated viewpoints, an improvement comprising matching features in the images by:

storing image data;

detecting the presence of features in the images represented by stored image data, comprising determining for image data representative of a plurality of different sized regions of a said image, values representative of the presence of features in said regions, and scaling

said values to account for variation in said values arising due to the size of the region used to determine said values; and

selecting image points as being representative of features in said image data on the basis of said scaled values.

142. A storage medium storing processor implementable instructions for causing a programmable processing apparatus to become operable to perform a method in accordance with at least one of claims 12 to 20, 37 to 53 or 61 to 68, 87 to 103 or 124 to 141.

143. A signal conveying processor implementable instructions for causing a programmable processing apparatus become operable to perform a method in accordance with at least one of claims 12 to 20, 37 to 53 or 61 to 68, 87 to 103 or 124 to 141.

144. An apparatus for generating characterization data characterizing features in an image comprising:

input means for receiving data representative of an image;

detection means for detecting the presence of features represented by image data received by said input

means, said detection means being arranged to determine, for image data representative of a plurality of different sized regions of the image, values representative of the presence of features in said regions; and

characterization means for characterizing image points selected as being representative of features in said image data on the basis of said detection by said detection means, by calculating characterization values for said features, wherein said characterization values are determined utilizing image data for regions of the image including said feature, and wherein said characterization means is arranged to determine said characterization values on the basis of image data for different sized regions, said size of said region being selected on the basis of the size of a said region utilized to detect said feature by said detection means.

145. Apparatus for generating characterization data characterizing image data in a manner substantially independent of rotational transformations of said image data comprising:

input means for receiving image data;

coefficient calculation means for generating a set of coefficients representative of the content of said image data; and

characterization value generation means for generating a set of characterization values utilizing said generated coefficients wherein said characterization values are substantially independent of rotational transformations of said image data;

characterized in that said coefficient calculation means comprises means for generating a set of complex coefficients comprising approximations of:

where $F_n(r)$ is a set of circular symmetric functions,

$$U_{n,m} = \int\int F_n(r) e^{im\theta} I(r,\theta) dr d\theta$$

$I(r,\theta)$ is an image represented by the received image data and n,m are natural numbers.

146. Apparatus for generating characterization data characterizing an image comprising:

input means for receiving data representative of an image;

feature detection means for detecting a plurality of features in the image; and

characterization means for characterising said features, said characterisation means being arranged to characterise portions of said image data representative

of regions of said image including said features, wherein said characterisation means is arranged to generate characterization data for a region of said image such that said characterization is substantially unaffected by transformations resulting in linear distortions of said region.

147. Apparatus for removing the effects of affine distortions from image data comprising:

input means for receiving image data;

transformation calculating means for determining a transformation to remove affine distortions from image data received by said input means; and

transformed image generation means for generating transformed image data corresponding to image data received by said input means transformed by said transformation determined by said transformation determination means;

wherein said transformation calculating means is arranged to determine the transformation to remove the effects of affine distortions from the received image data by determining a transformation such that the second moment matrix for said image transformed by said transformation is substantially equal to the identity matrix.

148. An apparatus for identifying features in images comprising:

input means for receiving data representative of an image;

detection means for detecting the presence of features in images represented by image data received by said input means, said detection means being arranged to determine, for image data representative of a plurality of different sized regions of said image, values representative of the presence of features in said regions; and

selection means for selecting image points as being representative of features in said image data on the basis of said detection by said detection means;

characterised in that:

said detection means is arranged to scale said values indicative of the presence of a feature in an image to account for variation in said values arising due to the size of the region used to determine said values.